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SURVEILLANCE AND DATA LINK ENHANCEMENT PROGRAM.(U)

JAN 77 E J KOENKE, J M GAROT

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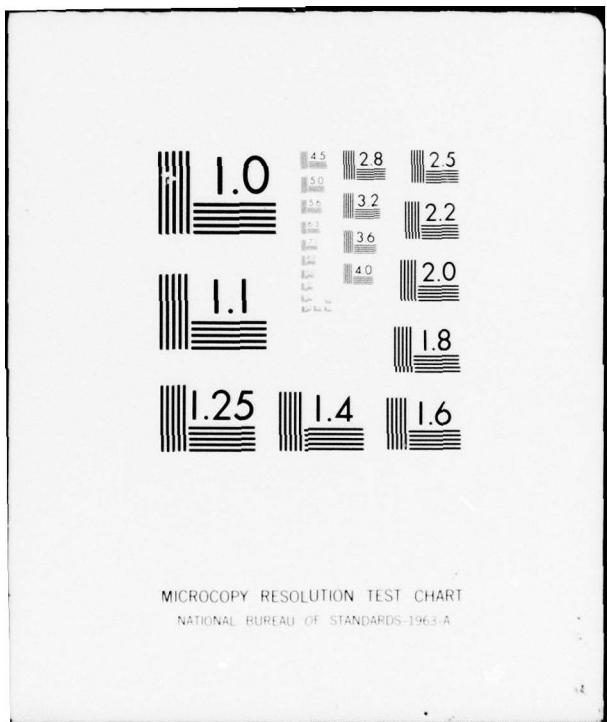
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SURVEILLANCE AND DATA LINK ENHANCEMENT PROGRAM



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16. Abstract On December 10, 1976, the Administrator, U. S. Federal Aviation Administration, and the Director General, French Civil Aviation, signed a Memorandum of Cooperation (MOC) to mutually establish a Surveillance and Data Link Enhancement Program. This document provides the background and rationale that prompted this program and describes the results of the plenary meeting held under the auspices of the MOC. The purpose is to jointly develop parameters for a common future (post-2000 A. D.) ATC system. This includes communications, surveillance, approach and guidance technology, and navigation. Specifically, it discusses: 1. Program Objectives; 2. Program Tasks; 3. Major Responsibilities; 4. Major Milestones; 5. Software Development Guidelines.		
407 002 Regarding Program Tasks, four areas are identified and discussed in some detail. They are: (See attached sheet.)		
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Item 16 continued:

1. Theoretical Study;
2. Simulation Analysis;
3. Flight Testing; and
4. Five-year Program Plan.

It has been jointly agreed by FAA and DGAC that these tasks will be completed during the initial year of the program.

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SURVEILLANCE AND DATA LINK

ENHANCEMENT PROGRAM

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CHAPTER I

BACKGROUND

The Air Traffic Control system is moving toward more sophisticated levels of automation in an effort to increase safety and reduce system cost. National Airspace System (NAS), Automated Radar Terminal System (ARTS), Conflict Alert, Discrete Address Beacon System (DABS) and Intermittent Positive Control (IPC) are examples of this trend. Fundamental to the success of the highly automated ATC system anticipated in the year 2000 and beyond is the ability of the system to perform automatic conflict detection and resolution. The key areas effecting this performance are surveillance system measurement accuracy and tracking capability in a variety of airspace environment and densities. This has been recognized by both the DGAC and the FAA and for this reason the following cooperative program has been developed.

Statement of the Problem:

A variety of surveillance sensors have been postulated for air traffic control application. Among these are DABS, AGDLS, Satellite systems and combinations of sensors. These systems differ in the type of measurement, measurement accuracy and measurement rate. (Typical measurement types are range, azimuth altitude systems; range, azimuth, elevation systems; trilateration systems, etc.) Further, differences exist in expected or achieved measurement accuracy and in the frequency with which measurements are made. The problem to be addressed in this effort is to examine generic measurement types over a range of accuracies and update rates in order to

determine the sensitivity of the performance of ATC tracking, automatic conflict prediction and automatic conflict resolution to these parameters.

In addition to measurement type, accuracy and rate, the performance of specific tracking algorithms and automatic conflict prediction and resolution techniques is highly dependent upon both the density of aircraft and the specific airspace in which they must operate. As a result, low medium and high density airspace in enroute and terminal areas including approach and landing must be considered since a specific techniques may perform well under one set of conditions and not under others.

Finally, one of the most important problems to be addressed is the formulation or establishment of the specific measures to be used to establish the performance of a system. In the area of tracking, accuracy, number of dropped tracks are among those measures which establish performance. In the area of automatic conflict detection, prediction accuracy false alarm rate and missed alarm rate establish performance. Conflict resolution performance is quantified by measures such as ATC interaction induced secondary encounters, and access time. Thus, three major interactive areas are identified as part of the stated objectives, namely:

- o Measurements
- o Environment
- o Performance

Each of which will be discussed in detail in the following sections.

Approach to the Problem

The basic approach to the problem stated above is to initiate a program of analysis, simulation, and flight tests oriented specifically to the areas detailed below.

Measurements

The recommended approach to this problem is to treat ATC surveillance systems in the generic sense rather than to deal with a specific system design. This approach is preferred since it can lead to the identification of requirements for future systems, either airborne or ground based, as well as compare a variety of fundamentally different approaches to surveillance to serve as the basis for the evaluate of existing and proposed concepts. Further, this approach has been successfully used in the past as is illustrated in Ref. 1. The candidate set of generic systems to be considered in this work as based upon the measurement coordinate frames and are listed below:

- o Cylindrical Measurement Systems
(range, bearing, altitude)

- o Spherical Measurement Systems
(range, bearing, elevation)
- o Cartesian Measurement Systems
(lateral x, y; altitude)
- o Elliptic Measurement Systems
- o Hyperbolic Measurement Systems

In addition to these measurement types, measurement accuracies will be treated as either fundamentally distance or angle measurements with distance ranging from 19 ft. to 500 ft. (one sigma) and angle from $.01^\circ$ to $.25^\circ$ (one sigma). Measurement updates rates will be evaluated from continuous to 0.1 Hz. It is expected that the above measurement types, accuracy and update rate ranges cover the spectrum of all existing, planned and potential surveillance system concepts. Initially, analysis and simulation will be used to generate the sensitivity curves relating the parametric variations listed above to tracking, automatic conflict prediction and resolution performance. Flight test will be used to validate selected points on these sensitivity relations.

Environment

Environmental conditions play an important role in system performance. A system which performs well in low density enroute airspace may behave poorly in high density terminal airspace. As a result, it is necessary

to evaluate the performance of tracking, automatic conflict prediction and automatic conflict resolution not only with respect to the basic measurement techniques but also relative to airspace type, density and flight phase. Thus, the following categories are recommended for inclusion in this work effort:

Airspace type

Terminal

Enroute

Density

High

Based on projections

Medium

thru the year 2000

Low

Flight Phase

Departure

Cruise

Approach (including closely spaced parallels)

Performance

In addition to identifying the basic criteria for quantifying the performance of tracking, automatic conflict prediction and resolution functions, specific algorithms or methods of realizing these functions must also be evaluated. The approach recommended for this phase of study includes both analysis and flight test. Analysis will be used to assess the effectiveness or performance of a specific tracking algorithm.

assuming perfect measurements or conversely the effect of accuracy and update rate under the assumption of optimal tracking of a known flight path. Similarly, partial sensitivities of automatic conflict detection algorithms assuming perfect measurements and tracking can be established. A complete but not totally exhaustive set of these sensitivities can be established by simulation and analysis for the various environments and measurement systems discussed above. Flight test would then be used to validate points on these sensitivity curves and would provide a means of modifying the analytical models. This would provide the necessary confidence in the results thus obtained to establish system requirements based upon trade off analyses of the simulation and flight test results and would represent the major output of this work.

REFERENCES

1. Canniff, John - "Air Traffic Management Conflict Prediction Sensitivity Analysis", MIT, Masters Thesis, June 1973.

CHAPTER II
PROGRAM OBJECTIVES

The objective of this program is to establish the effect of:

- measurement type
- measurement error
- measurement rate
- trajectory type

on the sensitivity of the performance of ATC tracking. Combination of various measurement types, measurement accuracies and update rates will be investigated as a function of trajectory type to yield specified tracking accuracy. These results could be used to specify future surveillance systems.

A large (as large as possible) set of measurement types, measurement errors and update rates will be studied. In order to avoid flight testing each variation, the work will be done mainly by the use of theory and/or simulation, validated to the extent possible with previously obtained flight test data.

It is more efficient and economical to perform a theoretical study than to develop a simulation. Therefore, emphasis will be placed on obtaining the maximum results possible using the theoretical approach. The theoretical approach to be used will be the Kalman covariance analysis method. However, with this method, only tracking accuracy for non accelerating flight can be theoretically evaluated. Thus, the plans for the

following work include:

- theoretical study for linear motion,
- simulation analysis for all the motions including curvilinear.

For linear motion, there will be a comparison and a validation between the theoretical study and the simulation analysis and flight tests will validate selected simulation analysis.

One of the conclusions of this work will be detailed 5-year program including points not being studied during the first year's effort.

The initial work is divided into 4 major areas:

- theoretical (covariance) analysis
- simulation analysis
- flight test
- future plan

CHAPTER III

TASKS

Task 1: Theoretical (Covariance) study

The goal of this task is to determine, for simplified trajectory models (i.e. non-accelerating flight), the relationship between:

- measurement coordinate frame type
- measurement accuracy
- measurement update rate
- trajectory type, and
- tracking accuracy.

The Kalman method will be used as the basic tool for this analysis and for the sake of simplicity. The effect of missing replies will be ignored in the initial work. The state vector will be defined as $(x, y, z, \dot{x}, \dot{y}, \dot{z})$; where x = north, y = east and z = down. Units will be expressed as nautical miles, feet and degrees.

To evaluate tracking accuracy, the trace of the covariance matrix will be computed separately for position and velocity (i.e. $x + y + z$ and $\dot{x} + \dot{y} + \dot{z}$) after the filter has stabilized. An additional output will be the number of updates needed to stabilize the filter.

Task 1.1 : Sensitivity Analysis

First, it is necessary to determine whether the tracking accuracy is independent of the measurement coordinate frame type since if this is true, the remaining study need be performed only for one type of

coordinate frame. If it is false, the remaining study has to be performed for all the frames. The specific frames to be initially considered are:

- cylindrical system (range , bearing , altitude)
- spherical system (range , bearing , elevation)
- cartesian system (lateral x, y , altitude z)

To make the measurement errors equivalent they will be calculated to be identical at a point situated 30 nautical miles from the origin of the frame and at an altitude of 10,000 feet. The baseline (1) errors for this work are assumed to be: $\sigma_r = 100$ feet, $\sigma_b = 0.1$ and $\sigma_h = 10$ feet (with quantification of 50 feet). AGDLS accuracies will also be used to compare simulation/theory and flight tests.

It will also be of interest to determine the linearity of the variation in tracker error with variation in measurement accuracy for various coordinate types.

The trajectory model will be linear (with radial, tangential and an arbitrary flight profiles) and at a constant altitude. Three different trajectory speeds (125 knots, 250 knots and 500 knots) will be used. The effect of driving noise (model error) will also be evaluated.

Initially, driving noise equal 1 ft/s^2 on each coordinate will be variation of tracker performance as a function of update rate will be determined for update rates of 12, 8, 4, 2, 1 seconds per update. Other rates such as 0.5 sec and 0.2 sec will be examined as necessary.

The outputs of the analysis will compare the trace of the covariance matrix with measurement type, accuracy, update rate, speed, etc.

Task 1.2 : Lateral and vertical cross coupling analysis

Since lateral and vertical position are not normally measured by the same method, and to simplify the equations, it would be advantageous to decouple the analytical equations. Therefore, the cross coupling effect between the lateral and vertical coordinates will be analyzed to determine if it is possible to decouple without introduction of significant error. Thus the task 1.1 studies will be performed with and without coupling in order to evaluate the cross coupling effect.

Task 1.3 : Aircraft Measurements

Previous studies have suggested the potential use of aircraft measurements for surveillance improvements. Turn rate, bank angle, ground speed and heading are among those measurements suggested. For purposes of this study, the effect of additional measurements will be considered by formulating them in the measurement matrix and thus their effect can

be evaluated by appropriate use of input parameters. A literature search will also be performed and correlation of these results with the literature will be attempted.

Task 1.4 : Other Linear Trackers

The use of Kalman trackers in operational systems is complex and costly. Therefore, this study will examine the error introduced from the use of sub-optimal linear trackers by mathematically developing the covariance analysis for fixed gain filters and then substituting these equations for the Kalman equations in the theoretical study. Comparison between results of Kalman and fixed gain filters will then yield the induced error.

Note - In order to maintain the flexibility needed to analyze several approaches, and avoid reprogramming, a modular computer program design must be developed. Details of software development guidelines are given in Part IV.

Task 2 : Simulation Analysis

The goal of this task is similar to that of task 1 but applies to both accelerating and non accelerating flights.

For non accelerating flights, a comparison with theoretical study performed in task 1 will be made. To perform this study, it is necessary to develop a simulation program composed of three basic parts:

- flight simulation
- tracking methods
- tracking evaluation.

Task 2.1 : Flight Simulation

Task 2.1.1 : Trajectories

First, there is the nominal trajectory which the aircraft (or pilot) intends to follow. For example, an enroute trajectory is composed of a number of retilinear segments. Next, there is the actual trajectory which is the one actually followed by the aircraft. This deviates from the nominal as a result of navigational errors, wind, pilotage, etc. The actual trajectory can be derived from the nominal trajectory by corrupting the nominal with noise. Finally, there is the measured trajectory which is the one observed by the surveillance system.

The measured trajectory can also be computed by adding noise to the actual trajectory being careful to be consistent with the neglected initially in order to simplify the problem. Provision will also be made to use flight test data rather than computed trajectories. The details of this work will be discussed in Task 3.

Task 2.1.2 : Operational Environment Considerations

This study is aimed at determining tracker accuracy for a given aircraft on a particular flight path and as such is not influenced by operational

factors such as airspace density. Phase of flight will however influence tracker accuracy and therefore this study shall consider various nominal trajectories appropriate to enroute terminal landing and departure for high medium and low performance aircraft.

Task 2.2 : Tracking Methods

It is recognized by both teams that very little is known on curvilinear/accelerated trackers. For purposes of first year work, it was agreed that two subtasks would be performed.

Task 2.2.1 : Literature search of available published material

Task 2.2.2 : Develop concepts for curvilinear/accelerated trackers
TO BE USED IN FUTURE SIMULATIONS

In this second subtask it should be pointed out that tracker performance as a function of trajectory type should be evaluated. This is:

- rectilinear tracker of both rectilinear and curvilinear trajectories, and
- curvilinear tracking of both rectilinear and curvilinear trajectories must be compared.

The objective will be to develop a single tracker or set of trackers which optimizes performance for both rectilinear and curvilinear flight profiles.

One possibility is to consider that driving noise is correlated from one measure to another so that we could use an augmented state vector e.g. x , y , z , \dot{x} , \dot{y} , \dot{z} , \ddot{x} , \ddot{y} , \ddot{z} . Another alternative is to examine adaptive filtering.

Task 2.3 : Tracker Evaluation

Task 2.3.1 : Comparison with Theory

The simulation will determine the variance of each element of the state vector on a scan by scan basis, and will utilize confidence limits to establish the degree of correlation between simulation and analysis.

Task 2.3.2 : Evaluation Techniques

To develop methods of comparing trackers with particular attention to curveilinear trajectories, it was agreed that both teams will look at this problem and exchange ideas at the next meeting.

Task 3: Flight Tests

Task 3.1 : Existing Data Exploitation

It was agreed that both teams wish to minimize the requirement for additional flight testing to support this program and therefore to use as much existing data as is available. Existing AGDLS and DABS data will be used to validate simulations. The AGDLS data will be most valuable in view of its high update rate of five per second. Two types of AGDLS data have been collected. The first is in a , ,

frame, the second in , only. This data is primarily applicable for terminal and landing phases of flight. Smoothing of the data will yield estimates of the actual trajectories and the raw data will yield the measured trajectory. This data can then be directly interfaced with the simulation program developed in Task 2.

Task 3.2 : Future Flight Test

Mutual determination of the necessity of further flight tests will result from the validation performed in Task 3.1.

Task 3.3 : Flight Test Plans

Depending upon the results of Task 3.2, appropriate flight test plans will be developed to complete simulation validation.

Task 4 : Five Year Program Plan

It was agreed that this subject is too broad to be discussed fully at the meeting. It was further agreed, however, that a 5 year plan must be a major milestone in the 1st year program.

Elements which must be considered as part of this plan have been identified as falling into two areas.

Task 4.1 : Major Development Efforts

Automatic conflict detection, automatic conflict resolution, data-link requirements, airborne measuring systems and air-to-air data link.

Task 4.2 : Minor Development Efforts

Effect of false correlation, missing replies, false replies on surveillance and the effect of environment and density on the above major areas.

Note that the possibility of Aerosat Wideband data for simulation validation was briefly discussed.

CHAPTER IV

MAJOR MUTUAL RESPONSIBILITIES

ASSIGNMENTS

Task 1 - Theoretical analysis - US team

Task 2 - Simulation - French team

Task 3 - Flight Test - French team

Task 4 - 5 Year Plan - Combined.

RESPONSIBILITIES

Task 1 - Theoretical analysis - will be performed totally by the US team and results and programs exchanged with the French team.

Task 2 - Simulation will be totally developed by the French team. Program interchange will then take place with the US team and both teams will share the large number of computer runs required in this study. Also, tracker evaluation techniques and curvilinear trackers will be mutually developed by both teams.

Task 3 - Flight Test - The French team will have the lead responsibility for this work. US support will be provided in the form of additional surveillance test data as well as test data reduction programs as available.

Task 4 - 5 Year Plan

This is a shared responsibility of both teams and is considered to be a major output of this first year program.

CHAPTER V

MAJOR MILESTONES AND SCHEDULE

The major milestones to be accomplished in the work are keyed to the scheduled meetings between the US team and the French team as specified in the MOU with the exception of the first milestone.

The first milestone consists of the development of a detailed technical approach and plan which includes task milestones, products and schedule for the tasks 1 and 2 which are major elements of the first year's effort and which are fundamental to the success of this joint effort. Completion of this first milestone is scheduled for Feb 21, 1977 and it is agreed by both teams that this will be the mailing date for the US plan for Task 1 and the French plan for Task 2.

At the end of the 3 month period (May 1, 1977), a meeting will be held in Washington. It is anticipated that the bulk of the programs for Tasks 1 and 2 will be developed by this time and that the meeting will concentrate on exchange of these programs, specification of the error analysis and simulation to be performed in anticipation of the 6 month meeting, information exchange on the results of the preliminary work on curvilinear trackers and tracker evaluation concepts, and interchange of flight test data and available data reduction programs.

At the end of the 6 month period (Aug. 1, 1977) a meeting will be held in Paris. This is a critical time for the success of this program since it

is at this point that results of both the U.S. theoretical analysis and the French simulation will be compared for the first time. An intensive working session is scheduled during which validation of theory and simulation will occur. Also at the working meeting, each team will present their theoretical work on curvilinear trackers and tracker evaluation techniques. A limited number of trackers and techniques will then be chosen for further study using both theory and simulation where possible and reasonable. Plans for the next set of validation to be made at the 9 month meeting will also be specified which requires determination of flight tests data to be used and simulations to be made.

At the end of the 9 month period (Nov. 1, 1977), a meeting will be held in Washington. Again this will be an intense working session at which flight test comparisons, simulation validation and theoretical validations will occur. Programs will be interchanged and Task 4 preparation of the 5 year plan, will be initiated. During the next 3 months, the simulation program will be used to make a Monte-Carlo analysis for tracker evaluation.

At the end of the 12 month period (Feb. 1, 1977), a meeting will be held in Paris. The first part of this meeting will be directed toward a formal evaluation of results, preparation of the year end report and preparation of a presentation for French and US management on the results of the first years effort a five year plan and a recommendation for continuing or discontinuing the effort. It is anticipated that at least 10 days

will be required to complete this work and at the end of this time management of both the US team and the French team would convene in Paris for the presentation of the results of the effort. A decision of management is thus required to determine whether this effort will continue.

CHAPTER VI
SOFTWARE DEVELOPMENT GUIDELINES

It was agreed by both teams that a common ground must be found to facilitate the mutual exchange of computer programs, test data and documentation in a clear and unambiguous manner. Toward this end, it was agreed that computer programs would be exchanged in the FORTRAN programming language and data in fixed format. Further, it is desired by both parties that the medium of this exchange be in the form of magnetic tapes.

The type of FORTRAN tentatively agreed to was the instruction set supported by Digital Equipment Corporation on their PDP 11/35 series of computers.

It was further agreed that computer programs would be written in an indented structure type format with one instruction per line of code together with a brief comment so as to make clear the intent of the instruction. All input and output parameters would be identified at the beginning of a program or subroutine with brief comments describing each parameter. Together with a description of the program itself. Further, program subroutines would be limited to approximately 1 page of printed output (maximum of two).

The documentation to be supplied with each program would be a flow-diagram detailing the logic. The detailing level of this flow-diagram

is at this point in time vague and will evolve as both teams find necessary.

The most difficult area to determine is the possibility of exchanging of 9-track type magnetic tapes. It was agreed by both sides to use the device (unit) approach rather than labelling files. Further, computer programs would be exchanged on a tape separate from data tapes so as to avoid complications. To determine the guidelines in this area, a mutual exchange of simple programs which exercise all possibilities of utilizing magnetic tapes and producing outputs was agreed upon. It is anticipated by both teams that there will be a quick determination of the utilization of magnetic tapes as the medium of information exchange as the hardware characteristics of the magnetic tapes are identified. It was agreed by both sides that data will be recorded in fixed format on magnetic tape. The structure of the data (e.g. date, state, vector and other information) will be identified along with the least significant bit (LSB) where needed for each variable in an accompanying document together with a FORTRAN computer program which can read and print the data.

It is recognized by both teams that the software guidelines are of necessity flexible to facilitate reaching a common ground. Therefore, it is anticipated that over the next several months the guidelines will take a more definite shape.

APPENDICES

APPENDIX A
GLOSSARY OF SYMBOLS

For purposes of this study, it has been agreed by both teams that the following list of symbols will be used. This will facilitate interchange of mathematical analyses.

A:	azimuth measurement
A/C:	aircraft
:	(beta) relative bearing angle measurement
:	d /dt
C:	scaler
D:	matrix
d_i :	initial distance to the i^{th} aircraft
d/dt :	differentiation with respect to time
:	(delta) first order variation operator
h:	difference in measured altitude between two aircraft
h:	$d h/dt$
:	difference in measured longitude between two aircraft
:	difference in measured latitude between two aircraft
t:	computation cycle between successive measurements
E, F:	probabilistic events
F:	matrix
:	(gamma) forcing function transition matrix
H:	matrix relating errors in state variables to errors in measurement variables

h : measured altitude
 h_i : altitude of i^{th} aircraft
 I : identity matrix
 \bar{K} : vector of Kalman Filter gains
 K, K : conversion factors, from RNAV frame to relative A/C frame
 k_0 : distance offset between the origin of the trajectory
frame and nominal collision point
 i : (lambda) measured latitude of i^{th} aircraft
 m : integer multiplying threshold distance, as measure
of miss distance
 \bar{m} : estimated value of \bar{m}
 $\bar{\bar{m}}$: (\bar{m}) true misc distance vector in relative A/C
frame with components
 n : integer multiplying error, as measure of threshold distance
 P : state covariance matrix after measurement update
 P_0 : initial covariance matrix
 $P()$: probability operator
 P_f : probability of false alarm
 P_m : probability of missed critical alarm
 P_n : probability of no alarm
 P_t : probability of true alarm
 P_x, P_y, P_z : probabilities based on normal distribution of
error along each component axis
: (phi) state transition matrix

i : (phi) measured latitude of i^{th} aircraft
 o : (phi) geocentric latitude of origin of trajectory frame
 Q : work matrix
 R_0 : measurement uncertainty matrix
 R : measured slant range (ground-based)
 r : measured range (air-to-air)
 r : dr/dt
 $:$: relative range vector, in relative A/C frame
 T : relative range vector, in trajectory frame
 A : alarm threshold vector
 C : critical miss distance vector
 RNAV : area navigation
 \bar{s} : state variable vector
 $:$: (σ) one standard deviation of error
 $:$: uncertainty in estimate of miss distance vector
 L : lateral component of
 V : vertical component of
 t : uncertainty in estimate of time of closest approach
 $:$: uncertainty in estimate of position state
 w : uncertainty in estimate of velocity state
 $R' A' h$: uncertainties in tracking radar measurements
 $x y z$: uncertainties in satellite radar measurements
 h : uncertainties in RNAV radar measurements
 $r h$
 $r h$: uncertainties in air-to air radar measurements
 T : alarm threshold value
 t : time

: (tau) true time of closest approach
 T_A : matrix, relating variations in air-to-air
 measurements and state variables
 T_R : transformation matrix, between trajectory frame
 and relative A/C frame
 T_S : transformation matrix, between trajectory frame
 and earth referenced frame
 \bar{v}_i : true velocity of i^{th} A/C
 \bar{w} : vector
 w_n : matrix of driving noise on state
 \bar{w} : relative velocity vector, in relative A/C frame
 \bar{w}_T : relative velocity vector, in a trajectory A/C frame
 \bar{x} : absolute position, velocity state vector, with
 component $x, y, z, \dot{x}, \dot{y}, \dot{z}$
 X_A, Y_A, Z_A : rectangular coordinate axes in relative A/C frame
 X_E, Y_E, Z_E : rectangular coordinate axes of earth referenced
 frame
 x_S, y_S, z_S : satellite position measurements, in earth reference
 frame
 x_0, y_0, z_0 : origin of trajectory frame, in earth reference
 frame
 \bar{x}_i : position vector of i^{th} A/C
 \bar{x}_i : velocity vector of i^{th} A/C
 \bar{y} : relative position state
 Y : covariance of relative position, velocity state

APPENDIX B

MEMORANDUM OF COOPERATION
FOR ADVANCE RESEARCH ON DATA
LINK PERFORMANCE

BETWEEN

THE UNITED STATES OF AMERICA
FEDERAL AVIATION ADMINISTRATION

AND

THE GOVERNMENT OF FRANCE
DIRECTION GENERALE DE L'AVIATION CIVILE

WHEREAS, the United States, represented by the Federal Aviation Administration (hereinafter referred to as FAA) and the Government of France, represented by the Direction Generale de L'Aviation Civile (hereinafter referred to as DGAC) have recognized a need to examine the potential operational limits of data links they have under development;

WHEREAS, there is a common interest in developing data links capable of the optimum possible performance under the worst possible conditions by the year 2000, in furtherance of which the DGAC is developing the "Air Ground Data Link System" (AGDLS) and the FAA is developing the "Discrete Address Beacon System" (DABS);

WHEREAS, FAA and DGAC would benefit from participating in a joint research program which would determine the optimum possible performance of data links under the worst possible conditions, and their limitations and relative suitability in the environment by the year 2000;

NOW, THEREFORE, the FAA and the DGAC agree to enter into a joint research program to determine the optimum possible performance of the two data links, their limitations and relative suitability in the air traffic environment anticipated in the year 2000, subject to the following terms and conditions:

1. The parties will jointly develop a suitable plan, setting forth the potential areas of work to be undertaken under this Memorandum of Cooperation (MOC).
2. The parties agree that each will assign to the joint research program, a maximum of two scientists/engineers of equivalent levels of education, expertise and experience.

3. The parties will exchange all data they currently maintain regarding the development of data links. Following the exchange of these data, the parties will convene a plenary meeting at a location to be mutually agreed upon. The purpose of this meeting is to provide a detailed outline of the following:

- a. the scope of the joint research program under the MOC;
- b. the division of work under this MOC;
- c. the locations where the specified work will be performed; and,
- d. the anticipated schedule for and results of the work to be performed under this MOC.

4. Four additional meetings will be held under this MOC - two in France and two in the United States. Each meeting will be approximately two weeks in duration, and will be attended by all members of the host nation's team and one member of the visiting nation's team.

- a. The first three of these working meetings are necessary to verify and reassess milestones; evaluate and criticize each party's work and analyses; perform critical measurements or programmation (computer models); and, to generally apprise each team of the accomplishments of the other.
- b. The parties, in the final working meeting, will review the entire joint research program and provide information necessary for each to produce a final report. The final reports will outline and assess the work performed under this MOC, evaluate the results achieved and the tools and techniques that were utilized, and state the conclusions that were drawn as a result of this MOC. In addition, the final reports will assess the benefits derived from this MOC, and recommend whether it is in the best interests of the parties to renew this agreement. The parties will timely exchange the final reports to permit renewal of this MOC prior to the date it terminates.

5. This MOC terminates one year after the meeting described in paragraph 3.

6. Each party will individually fund the costs of its respective activities and travel under this MOC. Activities and travel under this MOC shall be subject to budgetary appropriations and to the applicable laws and regulations of each country.

7. The designated officers for the control and administration of this MOC are:

France

Mr. Jean Marie Giraud
Directeur - Adjoint Direction
Generale de L'Aviation Civile
3, Avenue Friedland 75008 Paris

United States

Mr. Lucien V. Gormont
Engineering Staff Officer
International Division,
Office of Systems Engineering
Management
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington, D.C. 20591

Each party may change its designated officer at any time and shall notify the other party of the change.

8. The terms of this MOC may be modified upon the mutual agreement of the duly authorized representatives of the parties hereto.

9. The FAA and the DGAC agree to the terms of this Memorandum of Cooperation as indicated by the signature of their duly authorized officers.

United States
FAA

By:

Title : Administrator, FAA

Date:

France
DGAC

By:

Title: Director General,
Civil Aviation

Date:

APPENDIX C

POINTS OF CONTACT

In order to facilitate communications and establish points of contact between the French and US teams, the following team equivalents were established:

TITLE	FRENCH TEAM	US TEAM
Team Leader	Jean Marc Garot	Edmund J. Koenke
Deputy	Alban Michel	Andres Zellweger
Computer Analyst	Contractor	Del Weathers
Assistant	Orsay University Teaching Assistant	Mary Jane Minor
International Liaison	Jean-Marie Giraud	Lucien Gormont

To be named

Prospective FAA employee